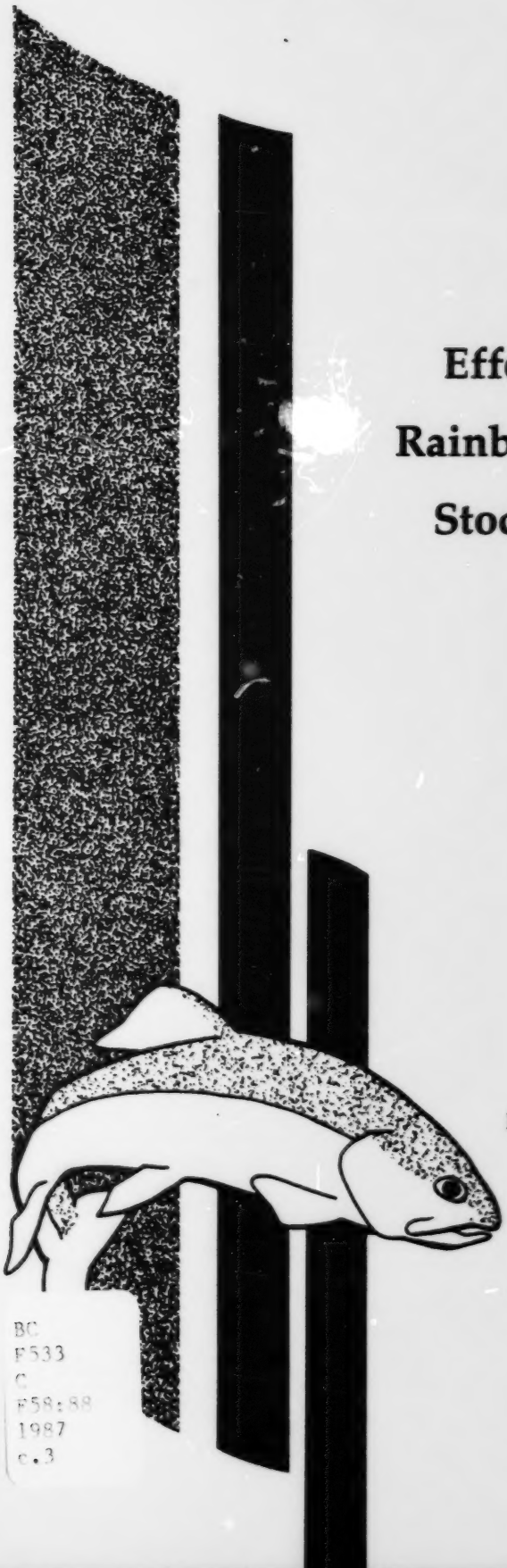

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by

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EFFECTS OF SIZE AT RELEASE IN RAINBOW TROUT (*SALMO GAIRDNERI*) STOCKED IN A WINTERKILL LAKE

by

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ABSTRACT

Tsumura, K., J.M.B. Hume, and B. M. Chan. 1987. Effects of Size at Release in Rainbow Trout (Salmo gairdneri) Stocked in a Winterkill Lake. Fisheries Management Report No. 88, 15 p.

Growth and maturation rates were compared in three graded groups of hatchery reared, Pennask Lake, yearling rainbow trout (Salmo gairdneri) (wild stock origin) stocked in a productive winterkill lake. The groups were downgrades, upgrades, and large upgrades. Mean lengths of the downgrades, upgrades, and large upgrade groups at stocking were 81, 93, and 109 mm, respectively.

Incidence of early sexual maturity in age 1+ males was 31%, 43%, and 51% for all the fish in each of the downgrade, upgrade, and large upgrade groups, respectively. In comparisons of two catchable length and weight categories ($\geq$ 255 mm or $\geq$ 225 g; $\geq$ 280 mm or $\geq$ 340 g), there were 50% more precocious males in the large upgrades than either of the other grades in all categories. Percent of males which were precocious in the sub-catchable size category was 13, 13, and 1.4 for all the fish in each of the downgrade, upgrade, and large upgrade groups, respectively.

In the large upgrades, 92% of the fish were $\geq$ 225 g and 55% were $\geq$ 340 g, when sampled 5.7 months after stocking into a winterkill lake. The downgrades and upgrades consisted of 47% and 65%, respectively, of fish $\geq$ 225 g, and 14% and 31%, respectively, of fish $\geq$ 340 g for the same growth period.

Stocking of large, graded fish into productive winterkill lakes is suggested as a technique to initiate a rainbow trout sports fishery in these lakes, and to reduce the numbers of precocious males in regularly stocked (non-winterkill) lakes.

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INTRODUCTION

Yearling rainbow trout reared in hatcheries can be graded into a size class that will include a large proportion of early maturing (precocious) males. These males spawn as 2-year-old rather than 3-year-old fish (Tsumura and Hume 1986; Hallingstad 1978). Early maturing males grow at a fast rate until fully mature and by the end of their second fall are usually larger than their immature counterparts (Tofteberg and Hansen 1986; Tsumura and Hume 1986). After the spawning period however, growth rates of the precocious males are retarded and the non-maturing fish become larger. Also, mortality may be high in comparison to the non-precocious fish (Tsumura and Hume 1987a). The physical spawning characteristics, including dark colouration and inferior flesh quality of these fish, are a poor substitute for the quality of rainbow trout expected by anglers in British Columbia interior lakes.

The rate of precociousness can be high in wild brood stocks used in the hatchery stocking programme. Early maturation as 2-year-old males ranges from 18% to 40% of the total annual hatchery production from Pennask Lake (Tsumura and Hume 1987b). Similarly, another stock (Premier Lake) has up to 40% of the total annual production developing into 2-year-old mature males (Hume, Lemke, and Tsumura 1986; Houston 1981).

There are many lakes in British Columbia which are categorized as winterkill lakes and are not stocked (Appendix 1). Some winterkill lakes have recently been brought into fish production by artificial circulation (Ashley 1987; Halsey and McDonald 1971), and by stocking with Eastern brook trout (Salvelinus fontinalis), a species more tolerant to low dissolved oxygen concentrations (Halsey and McDonald 1971). Catchable size fish can also be stocked in these lakes, but the benefit/cost would be too low to warrant production on a large scale (Parkinson 1985). These applications, therefore, cannot be implemented on the majority of winterkill lakes due predominantly to budgetary constraints. Eastern brook trout could be produced on a larger scale, but these fish are still susceptible to winterkill and, among all the sports fish in British Columbia, rank very low in the species preferred by anglers (Reid 1986).

Winterkill lakes are generally very productive and are suitable for supporting a trout population during the ice-free period (Lawler et al. 1974; Larkin 1954). Although these lakes cannot sustain a rainbow trout population throughout the winter months when covered with ice and snow, fish thrive during the open water period. Rainbow trout (age 1) stocked after ice-off may grow to a catchable size by September and a sports fishery might be possible. This fishery should extend through to

February in most winterkill lakes before critical oxygen depletion occurred in the lake (Ken Ashley, pers. comm.).

This study was undertaken to determine whether the larger, faster growing yearling rainbow trout could be graded to include a large number of precocious males, and could be utilized to develop a fishery in a winterkill lake. Growth rates should be high enough that fish will reach a catchable size by early fall, and a fishery could be developed at minimal costs, where none was existent before. An intensive fishery in the fall and winter could catch most of the trout before the lake winterkilled and before precocious males deteriorated in quality from the physiological process of sexual maturation. At the same time, regularly stocked lakes (non-winterkill) would benefit as a large proportion of the early maturing males should have been graded out and a major proportion of the yearlings stocked into these lakes would be later maturing.

STUDY AREA

Horseshoe Lake is a highly productive winterkill lake situated 40 km south of Kamloops, British Columbia, (50° 28′ N, 120° 10′ W), at an elevation of 1,113 m. Surface area is 15 ha with 34% littoral area. It has a maximum depth of 6.0 m and a TDS of 240 mg/L. The estimated probability of rainbow trout winterkill is 80% (Brian Chan, pers. comm.). Prior to this study, 5,000 to 8,000 Eastern brook trout (Salvelinus fontinalis) were stocked annually from 1978 to 1984, and a few had carried over to the study year. The lake was open to angling year round.

METHODS

The three size groups used for the comparison were progeny from the 1984 spawning run at Pennask Creek. They were reared at the Summerland Trout Hatchery where downgrades and upgrades were separated into groups less than 0.5 g and equal or greater than 0.5 g. This grading took place at the time fry were moved from the indoor rearing troughs to the outdoor raceways in late September, 1984. The upgrades were the fish to be released by the Summerland Trout Hatchery in their stocking programme the following spring. The large upgrades were comprised of fish sorted on May 8, 1985 from the hatchery upgrades using a slotted wood grader with an aperture size of 8.9 mm. The downgrades and upgrades used in the study were randomly collected from the raceways and fish in the large upgrade size were not removed from either of these groups. There were 1,700 fish in each group and were all marked by a fin or maxilla clip. The fish were measured and clipped on May 8, 1985 and stocked into Horseshoe Lake on May 13, 1985.

The rainbow trout were sampled in Horseshoe Lake on October 30, 1985, 175 days (5.7 mo) after the liberations, using

various mesh size gillnets made into gangs. Each gillnet was 2.4 m deep by 15.2 m long. Gangs consisted of nets with 38.1, 50.8, 63.5, and 76.2 mm stretched mesh sizes. Lengths, weights, clips, sex, maturity and gonad weights were collected shortly after capture. The fish were classified as mature (precocious) or immature (non-precocious) by visual examination of the gonads. Precocious fish were deemed ready to spawn the following spring.

In the analysis of lengths and weights, fish were compared in two catchable size classes. One catchable size category consisted of fish greater or equal to 255 mm or 225 g. The minimum size for the second, a large catchable size category, was 280 mm or 340 g. The large catchable size category was a subset of the first catchable size category.

RESULTS

Pre-stocking Characteristics

The mean lengths and weights (Table 1) of the three grade classes were different at time of stocking ($P < 0.05$). However, there was considerable overlap between all three classes (Fig. 1). The downgrades consisted of 22% by length (> 90.0 mm) or 14% by weight (> 8.0 g) of the large upgrade size category. The upgrades consisted of 54% by length or 41% by weight, of the large upgrade size category.

Table 1. Initial lengths and weights at Summerland Trout Hatchery on May 8, 1985.

	Downgrades	Upgrades	Large Upgrades
Number	240	280	246
Length (mm)			
Mean	81.3	92.6	109.2
SD	11.8	15.4	12.3
Weight (g)			
Mean	5.6	8.6	13.6
SD	2.6	5.5	5.9

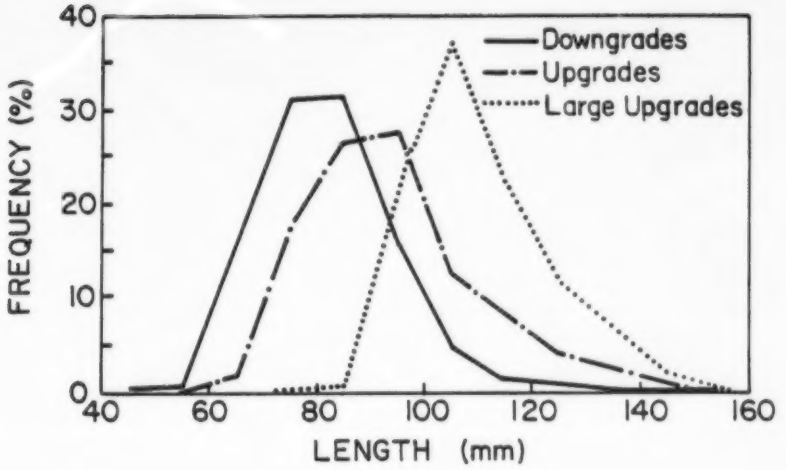

Fig. 1A. Length frequency of the three grade classes at Summerland Trout Hatchery on May 8, 1985. (Downgrades, N = 240; Upgrades, N = 280; Large upgrades, N = 246).

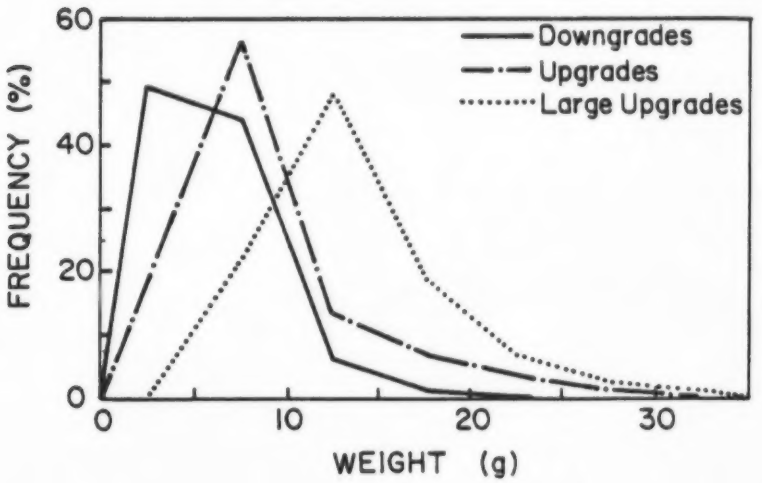

Fig. 1B. Weight frequency of the three grade classes at Summerland Trout Hatchery on May 8, 1985. (Downgrades, N = 240; Upgrades, N = 280; Large upgrades, N = 246).

Maturity and Size in Horseshoe Lake

There were 20% more precocious males (Table 2) in the large upgrades than in the downgrades (G test, $P < 0.05$) after 5.7 months in Horseshoe Lake. Precociousness rates in the upgrades were not significantly different from either of the other grades. Early sexual maturation among females was negligible (0.9% in large upgrades). Sex ratios were not significantly different from 1:1 in any group, nor were there any differences between grades (G test, $P > 0.05$).

There were significant differences in final lengths and weights between all three grades ($P < 0.05$). Large upgrades were 15% and 10% greater in mean length than the downgrades and upgrades, respectively. They were also 58% and 30% greater in mean weight for the same respective grades (Table 3). Trout > 0.5 kg comprised 14% of the large upgrades compared to 1% and 8% for the downgrades, respectively.

Table 2. Comparison of sexual maturity in the three graded groups of rainbow trout sampled with gillnets in Horseshoe Lake.

	Males				Females			
	Non-Precocious		Precocious		Non-Precocious		Precocious	
Group	n	%	n	%	n	%	n	%
Downgrades (N = 103)	18	17.5	32	31.1	53	51.4	0	0
Upgrades (N = 86)	8	9.3	37	43.0	41	47.7	0	0
Large upgrades (N = 106)	4	3.8	54	50.9	47	44.3	1	0.9

Large upgrade precocious males were also significantly larger than all other groups sorted by sex and maturity (Table 3). These males were 22% and 75% greater in mean length and weight, respectively, than fish in the other two grades. They also grew at a faster rate than the other fish in the same grade. These males grew at an average rate of 1.9% of ln body weight per day compared to 1.7% and 1.8% for the non-precocious males and females, respectively.

Table 3. Comparison of length, weight and instantaneous growth rates 175 days after liberations into Horseshoe Lake.

A. Fork Length

Grade	Males				Females				All Fish
	Non-Precocious		Precocious		Non-Precocious		Precocious		
	n	mm	n	mm	n	mm	n	mm	mm
Downgrade (N = 103)	18	247.3	32	257.0	53	243.2	0	-	248.2
Upgrade (N = 86)	8	238.0	37	267.3	41	257.0	0	-	259.7
Large Upgrade (N = 106)	4	260.0	54	297.6	47	277.5	1	310.0	287.4

B. Weight

Grade	Males		Females		All Fish
	Non-Precocious	Precocious	Non-Precocious	Precocious	
	g	g	g	g	g
Downgrade (N = 103)	205.8	261.4	213.4	-	227.0
Upgrade (N = 86)	185.0	311.9	265.0	-	277.7
Large Upgrade (N = 106)	260.0	407.2	312.9	420.0	359.9

C. Instantaneous Growth Rates (weight)

Grade	Males		Females		All Fish
	Non-Precocious	Precocious	Non-Precocious	Precocious	
	G	G	G	G	G
Downgrade (N = 103)	.0206	.0220	.0208	-	.0211
Upgrade (N = 86)	.0176	.0205	.0196	-	.0198
Large Upgrade (N = 106)	.0168	.0194	.0179	.0178	.0186

The large upgrades had more fish in the catchable size categories than either of the other two grades (Table 4). In the catchable size category, 92% of the large upgrades were ≥ 225 g and 50% of these fish were precocious males (Table 5). The proportion of precocious males was 19% for the downgrades and 31% for the upgrades in the same catchable size category.

Table 4. Catchable fish in two size categories for each grade.

Grade	Catchable Size ≥255 mm n	%	≥225 g n	%	Large Catchable Size ≥280 mm n	%	≥340 g n	%
Downgrade (N = 103)	45	43.7	48	46.6	15	14.7	14	13.7
Upgrade (N = 86)	43	50.0	56	65.1	27	31.4	27	31.4
Large Upgrade (N = 106)	94	88.7	98	92.4	72	67.9	59	55.7

Table 5. Precocious males in two catchable size categories for each group.

Grade	Catchable Size ≥255 mm n	%	≥225 g n	%	Large Catchable Size ≥280 mm n	%	≥340 g n	%
Downgrade (N = 103)	17	16.5	20	19.4	8	7.8	6	5.8
Upgrade (N = 86)	21	24.4	27	31.4	17	19.8	15	17.4
Large Upgrade (N = 106)	52	49.1	53	50.0	45	42.4	41	38.7

In the large catchable size category, 56% of the large upgrades were ≥ 340 g and 39% of these fish were precocious males. The downgrades and upgrades were comprised of 6% and 17% precocious males, respectively, in this catchable size category. The sub-catchable size category fish (< 225 g) was comprised of 0.9% precocious males in the large upgrades, and 12% for the downgrades and upgrades (Table 6).

Table 6. Precocious males in the sub-catchable size category for each grade. (N_T = total sample size, N_S = number of sub-catchable size trout, n = number of precocious males.)

	Sub-catchable Size							
	< 255 mm (length)				< 225 g (weight)			
	N_S	%	n	%	N_S	%	n	%
Downgrade (N_T = 103)	58	56.3	15	14.6	55	53.4	12	11.6
Upgrade (N_T = 86)	43	50.0	16	15.5	30	34.9	10	11.6
Large Upgrade (N_T = 106)	12	11.3	2	1.9	8	7.5	1	0.9

DISCUSSION

This study suggests that a large proportion of precocious males can be graded out as yearlings and could be utilized to develop a fishery in productive winterkill lakes. A laboratory experiment conducted by Tsumura and Hume (1986) indicated that, for groups of Pennask Lake rainbow trout graded at 11 months of age, fish $\geq$ 115 mm (average 22 g) consisted of 50% precocious males compared to 11% for fish size 80 to 94 mm and 2% for fish size $\leq$ 70 mm when sampled in late October. Only the precocious males in the large size class in that study grew to our catchable size category for length ($\geq$ 255 mm) or weight ($\geq$ 225 g). Similar trends were observed in our study using a grading technique more applicable to hatchery operations and management.

Precocious rainbow trout will grow to a catchable size by the end of their second fall, if conditions are suitable. However, even though the precocious males are among the faster growing fish in regularly stocked lakes, only a few will attain the same weight gain as in a productive winterkill lake. Out of 145 precocious males sampled by Tsumura and Hume (1987b) from seven regularly stocked lakes (non-winterkill) for the same brood and year class, 23 (16%) weighed more than 225 g and only 6 (4%) weighed more than 340 g. This could be due to the effect of angling pressure on the population, but in a study conducted by Sidney (1986) on Hatheume Lake (catch-and-release fishery) using Pennask Lake stocks, only 16% of the precocious males weighed more than 225 g and only 4% weighed more than 340 g. These males were from a previous stocking and were 7 months older than those in our study. This apparent slow growth combined with an

increase in mortality rates after the spawning period (Tsumura and Hume 1987a, Tofteberg and Hansen 1986) supports our suggestion that precocious males can be put to better use, if graded out from the regular hatchery stocking programme.

The proportion of precocious males in the sub-catchable size was low (12% for fish < 225 g) in all three grades in our study. Most of these smaller size fish will mature at the age of three years or later, and include a major portion of the population required to sustain a fishery in stocked lakes from year to year. These sub-catchable size fish, which were probably the smaller size fish at time of initial stocking (Lawler et al. 1974), made up 35% of the upgrades and 53% of the downgrades. As suggested by Tofteberg and Hansen (1986), later maturing fish overtake the precocious male in size and are larger in the third year (age 2+) than these fish. In their study, fish maturing in the fourth year consisted of the smallest fish at an age of 11 months; however, growth rates were not significantly lower than those which matured at the age of three years. This suggests that although the average size of trout may be smaller initially, regularly stocked lakes (non-winterkill) would also benefit from a grading programme conducted prior to stocking, once the later maturing age classes are established.

It is apparent that date of release, size of fish at release, and stocking densities can be critical in obtaining high growth rates in winterkill lakes. Lakes stocked with fry 25 to 38 mm long in mid-June by Johnson et al. (1970) weighed 113 g by late October, but fish 63 to 76 mm long stocked in April and May averaged over 300 g. The stocking density in these lakes averaged 80 fish/ha. Rainbow trout stocked in prairie ponds by Lawler et al. (1974) after ice-off in May and harvested in the fall and early winter averaged 116 to 391 g. In ponds stocked at densities less than 2500 fish/ha, average size was 266 g; but in ponds stocked in excess of 4500 fish/ha, average size declined to 130 g.

The foregoing studies suggest that stocking of winterkill lakes should be done soon after ice-off and densities kept low to ensure the growth of fish to a catchable size. Our stocking density of 340 fish/ha in Horseshoe Lake could be applicable to most winterkill lakes in British Columbia; however, stocking more lakes at lower densities would probably benefit anglers the most. Maximum stocking densities of 50% of the yearling capacity, suggested by Stringer et al. (1980) for British Columbia lakes, could be followed as a guideline. Winterkill lakes with over-winter survival should not be restocked, but kept open for fishing. Rainbow trout over 1 kg could be expected from these lakes after two summers of growth (Lawler et al. 1974).

Summerkill is probably the major problem associated with developing a fishery potential of small eutrophic lakes (Lawler et al. 1974). Several investigations have been carried out in recent years, but this phenomena is not yet fully understood. In prairie ponds, collapse of heavy algal blooms in late summer along with rapid decomposition of dead algal cells (Baricia 1975) and thermal instability (mixing) in lakes in which these conditions are present (Papst et al. 1980), have been implicated with lake oxygen depletion resulting in summerkill.

Summerkill prediction techniques for prairie ponds are discussed by Baricia (1975). The least time-consuming technique involves obtaining NH_3-N concentrations in late winter and it is suggested that lakes exceeding 1000 μg/litre should not be stocked. If this information is not available, lakes known to have heavy summer algal blooms should not be stocked until summerkill risk is identified.

Another problem associated with rearing trout in small winterkill lakes may be muddy flavour of the fish. Muddy flavour can be determined by trial plantings of rainbow trout (Lawler et al. 1974). Lakes where this characteristic appears could be eliminated from stocking in subsequent years and replaced with other lakes. The delayed opening of the fisheries suggested in this stocking programme could be advantageous as the muddy flavour condition appears to dissipate towards October (Johnson et al. 1970).

Summary of Management Implications

1. Small winterkill lakes which are presently barren and easily accessible can be brought into a fall and winter fishery at minimal cost and effort.

2. In October, the large upgrades consisted of 92% catchable size trout ($\geq$ 225 g) of which 50% were precocious males.

3. These winterkill lakes should be closed to angling until fall. An "opening" could generate an increase in effort at a time of declining interest as fishing a "new" lake may appeal to anglers.

4. A large proportion of the trout will be caught in a few days and throughout the winter. Losses due to lake winterkill should be minimal.

5. A large number of precocious males will be utilized in a fishery while still in prime condition and before an increase in mortality during the spawning and post-spawning period.

6. There should be a proportional decrease in the number of precocious males in regularly stocked lakes (non-winterkill), and this could benefit a quality lakes fishery.

7. Large yearling rainbow trout results in larger 1+ fish; therefore, it would be advantageous to stock winterkill as well as non-winterkill lakes with largest yearlings possible. Grading should still be carried out to separate precocious males.

8. The large upgraded trout should be stocked as early as possible after ice-off, if conditions are suitable.

9. Stocking densities should be kept low. A maximum density of 50% of the yearling capacity calculated from the stocking formula for British Columbia lakes is suggested.

10. Winterkill lakes with over-winter survival should be stocked in alternate years.

11. Summerkill risk should be determined prior to stocking.

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Appendix 1. List of winterkill lakes which may be suitable for stocking with large upgraded yearling rainbow trout.

Region 3. (Lakes suggested by Brian Chan)

Lake	MU	Surface Area (ha)	Probability of Winterkill (%)
Sawmill	12	12	75
Upper Lundbom	12	12	90
Andrew	19	5	75
Bush	19	4	70
Connant	19	11	85
Desmond	19	18	65
Dwand	19	18	75
Eve	19	6	85
Homfray	19	20	65
Hughes	19	12	75
Little Lodgepole	19	2	80
Little Mildred	19	3	85
Mab	19	36	80
Memanteau	19	15	80
Morgan	19	8	65
Quanville	19	8	85
Rey	19	20	85
Roper	19	6	70
Saxon	19	9	80
Sheep	19	7	90
Sophia	19	11	85
Timber	19	5	70
Separation	20	24	70
Stevens 1	20	5	70
Stevens 2	20	16	70
Stevens 3	20	4	70
Coyote	27	4	70
Martin Meadows	27	10	65
Orchard	27	11	70
Struthers	27	4	75
Long	28	22	75

Region 4. (Lakes suggested by Alan Martin)

Edith	2	12	10
Englishman	3	8	90
Lost	3	4	90
Lund	3	12	10
Sevenmile	3	2	30
Mineral	5	6	10
Bartholomew	20	31	50
Larchwood	20	15	30
New	20	28	30
Campbell	21	6	100
Dibble 2	21	8	90
Northstar	22	24	20
Spring	22	8	10
Tie	22	126	30
Wapiti	22	15	20
Lost	23	4	30
Summit	23	17	30
Enid	26	22	90
Gavia	34	4	30
Dogsleg	34	9	90
Marion	35	18	30

Region 5. (Lakes suggest by Bill Westover)

Able	2	30	
Big	2	111	
Dewer	2	41	100
Eveline	2	47	75
Irish	2	28	75
PGE Reservoir	2	4	100
Simon	2	57	90
Tad	2	36	100
Buckskin	14	27	90

Sub-region 8. (Lakes suggested by Dave Smith)

Toy	2	2	50
John Burns	5	2	100
Swan	6	2	100
Spuxunne	6	12	100
Vinson	6	5-20	100
Farleigh	8	15	50
Margine	10	2	100
Duo Via	11	8	50
Lily	11	1	100
Linden	12	9	10
Martin	12	2	100
Rainy	14	4	100
Hudson Bay	21	6	50
Barbe	23	15	100

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